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Oikawa

(10) **Patent No.: US 9,115,713 B2**
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(54) **HIGH-PRESSURE PUMP**

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(73) Assignee: **DENSO CORPORATION**, Kariya (JP)

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(51) **Int. Cl.**

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F04B 53/08	(2006.01)
F02M 59/44	(2006.01)
F02M 53/00	(2006.01)
F04B 1/04	(2006.01)
F04B 53/16	(2006.01)

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CPC ***F04B 53/08*** (2013.01); ***F02M 53/00*** (2013.01); ***F02M 59/44*** (2013.01); ***F04B 1/0404*** (2013.01); ***F04B 1/0421*** (2013.01); ***F04B 53/16*** (2013.01); *F02M 37/0029* (2013.01); *F02M 37/0041* (2013.01); *F02M 37/0047* (2013.01); *F02M 59/102* (2013.01); *F02M 59/367* (2013.01); *F02M 63/0265* (2013.01)

(58) **Field of Classification Search**

CPC F02M 37/0041; F02M 37/0047; F02M 37/043; F02M 59/027; F02M 59/44; F02M 59/466; F04B 1/0421; F04B 1/0404; F04B 53/16; F04B 53/08; F04M 53/00; F04M 59/367; F04M 59/102; F04M 37/0029; F04M 63/0265

USPC 92/1; 82/144; 60/456; 123/456; 417/470

See application file for complete search history.

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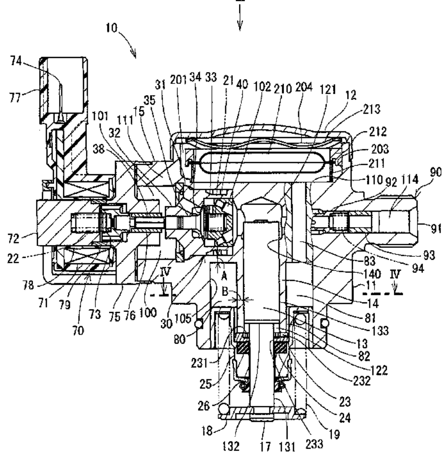
(74) *Attorney, Agent, or Firm* — Nixon & Vanderhye P.C.

(57) **ABSTRACT**

A high-pressure pump includes a plunger for pressurizing a fuel, a cylinder accommodating the plunger reciprocatably in its axial direction and a pump body. The pump body defines a pressurization chamber, a low-pressure fuel passage hydraulically connecting a fuel inlet and the pressurization chamber, and a discharge passage. The pump body further defines a cylindrical space around the cylinder. The fuel flows into the cylindrical space from the low-pressure fuel passage so as to cool the cylinder. The entire outer surface of the cylinder can be surely cooled.

10 Claims, 12 Drawing Sheets



(51) **Int. Cl.**

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F02M 59/36	(2006.01)
F02M 63/02	(2006.01)
F02M 59/10	(2006.01)

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FIG. 1

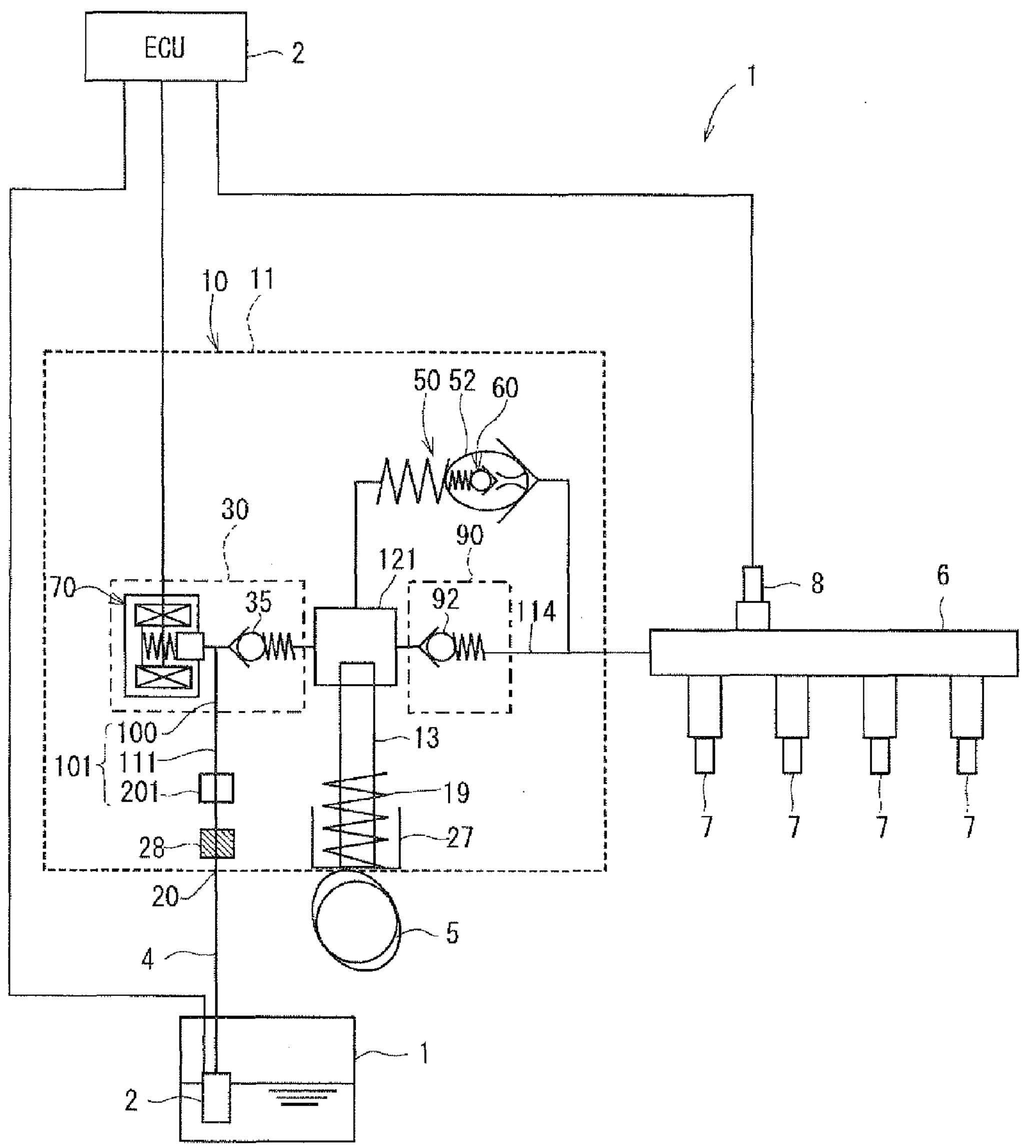
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FIG. 2

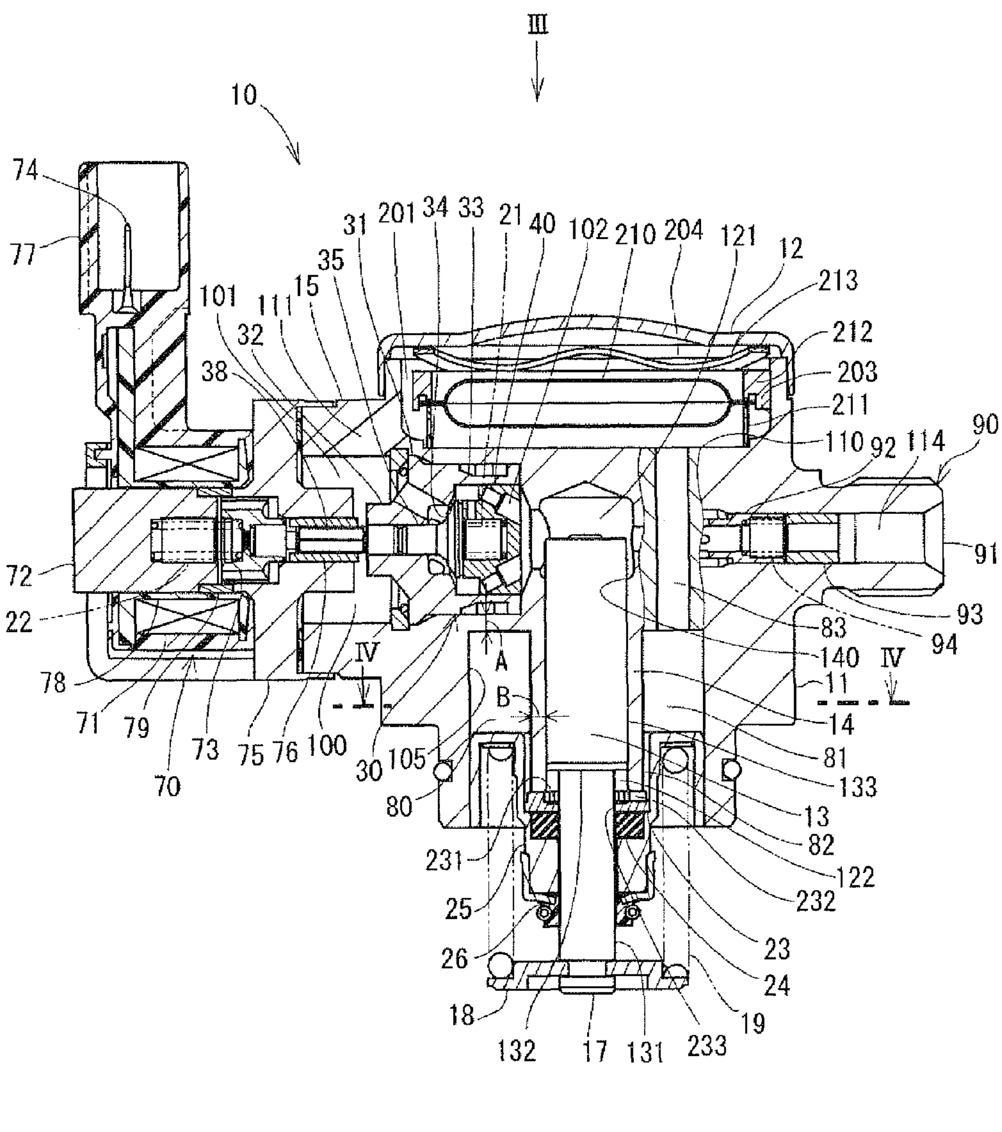
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FIG. 3

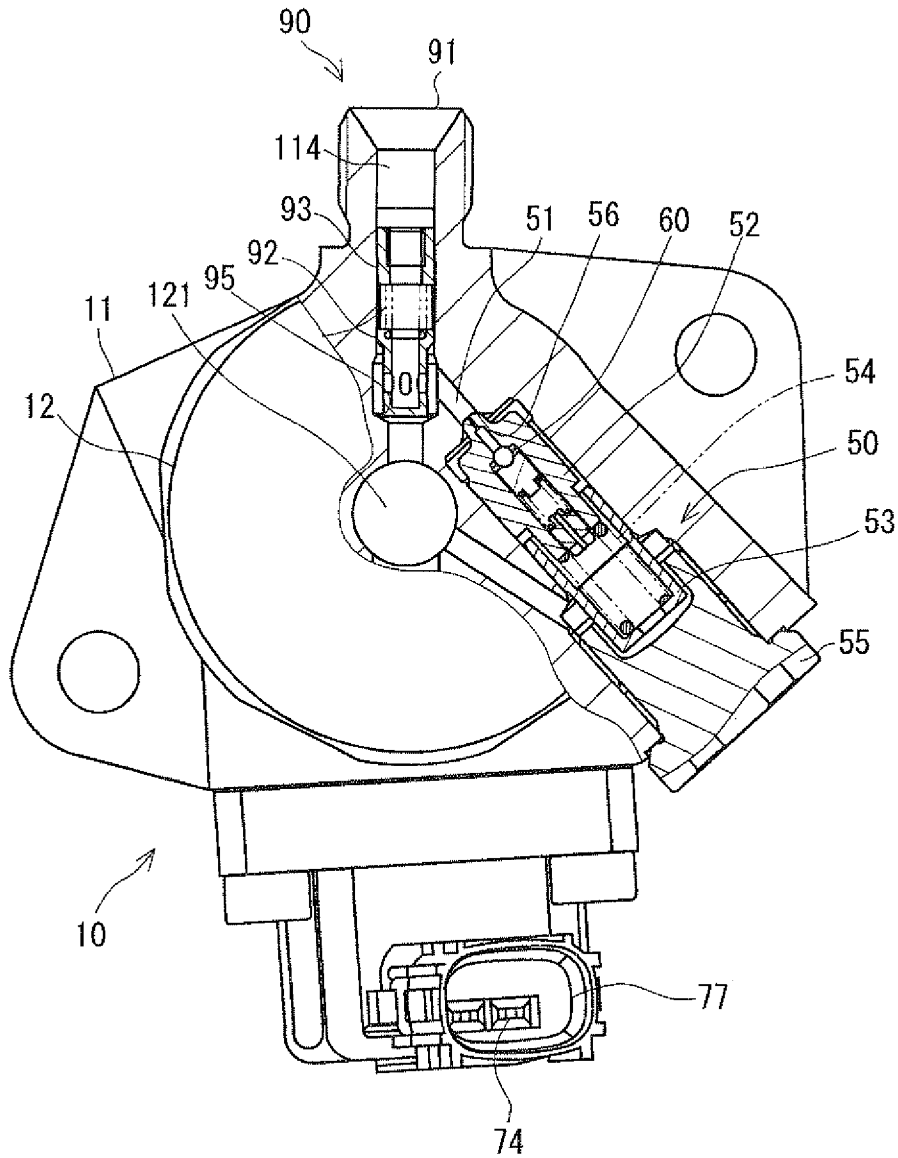


FIG. 4

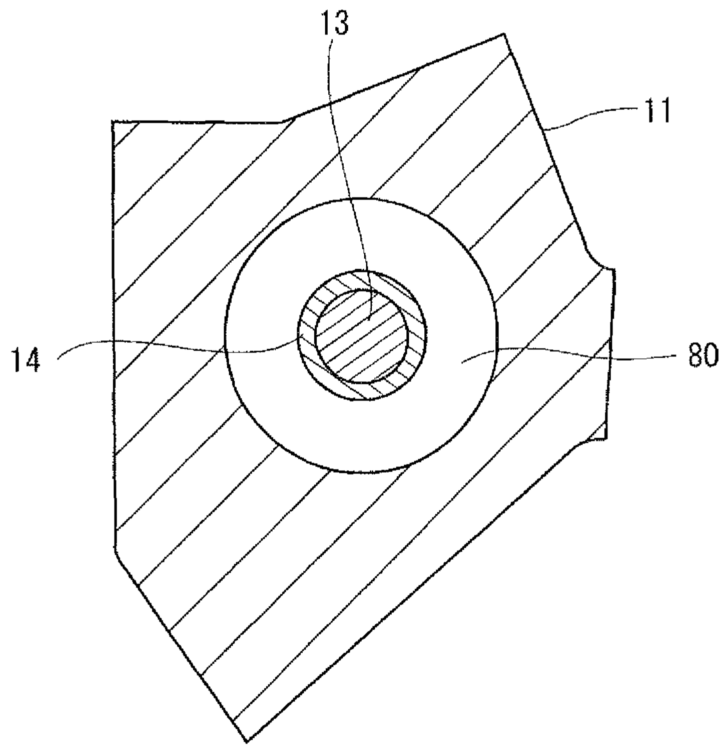
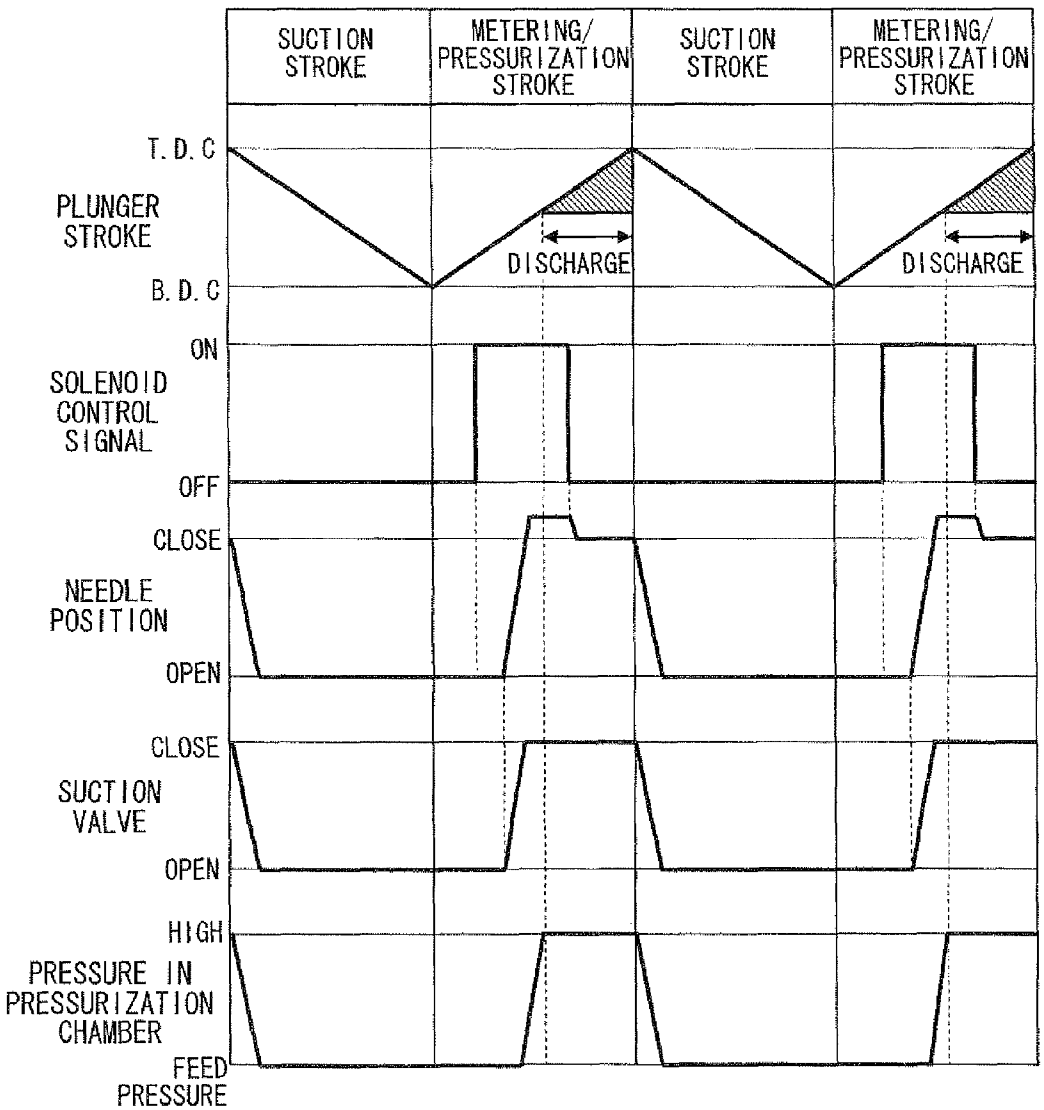


FIG. 5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SUCTION STROKE
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PRESSURE IN PRESSURIZATION CHAMBER
FEED PRESSURE

FIG. 6

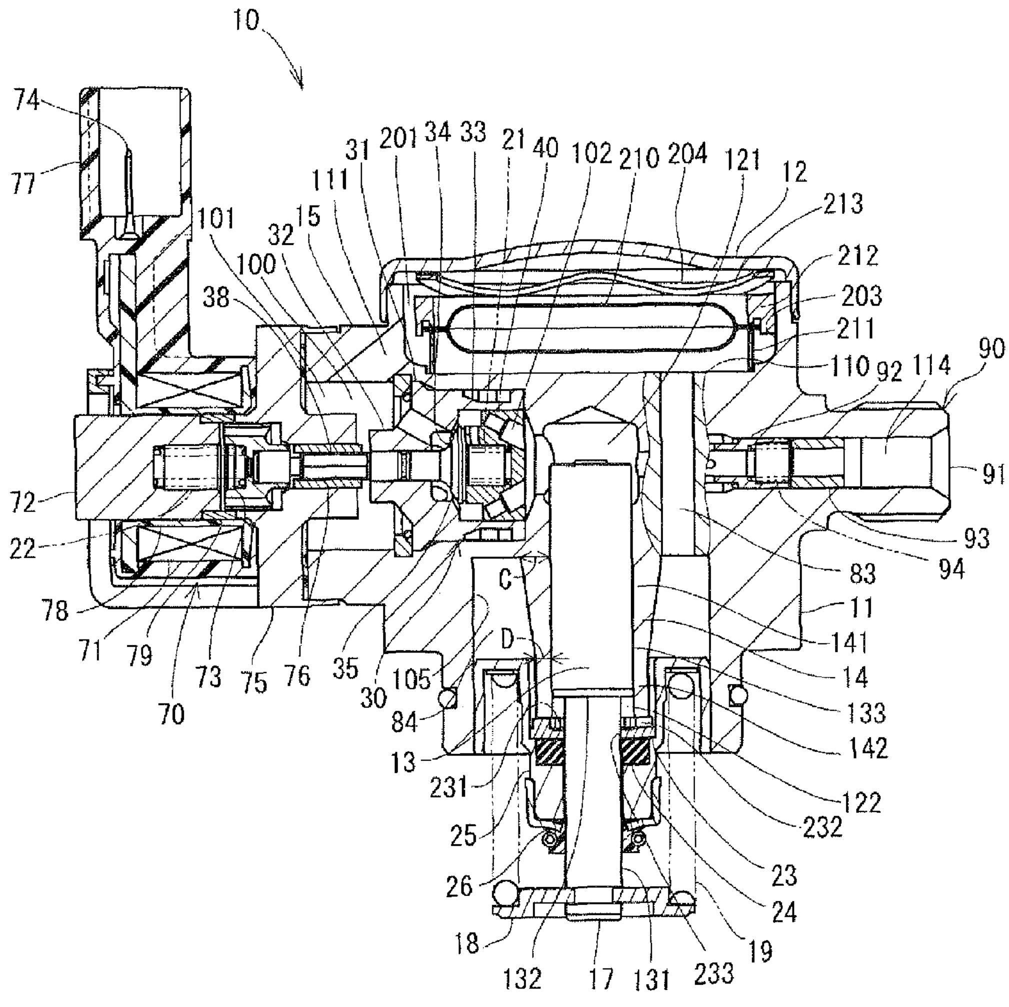

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FIG. 7

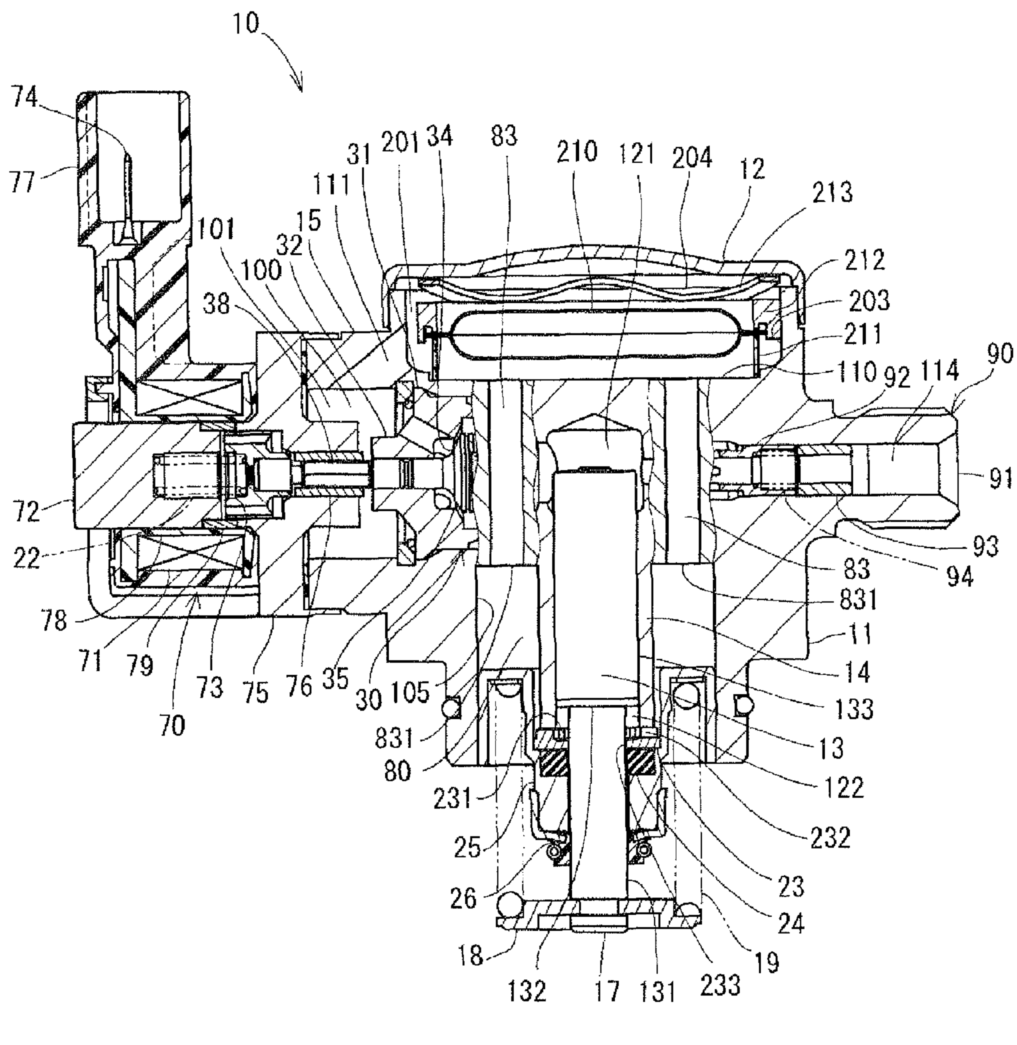
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FIG. 8

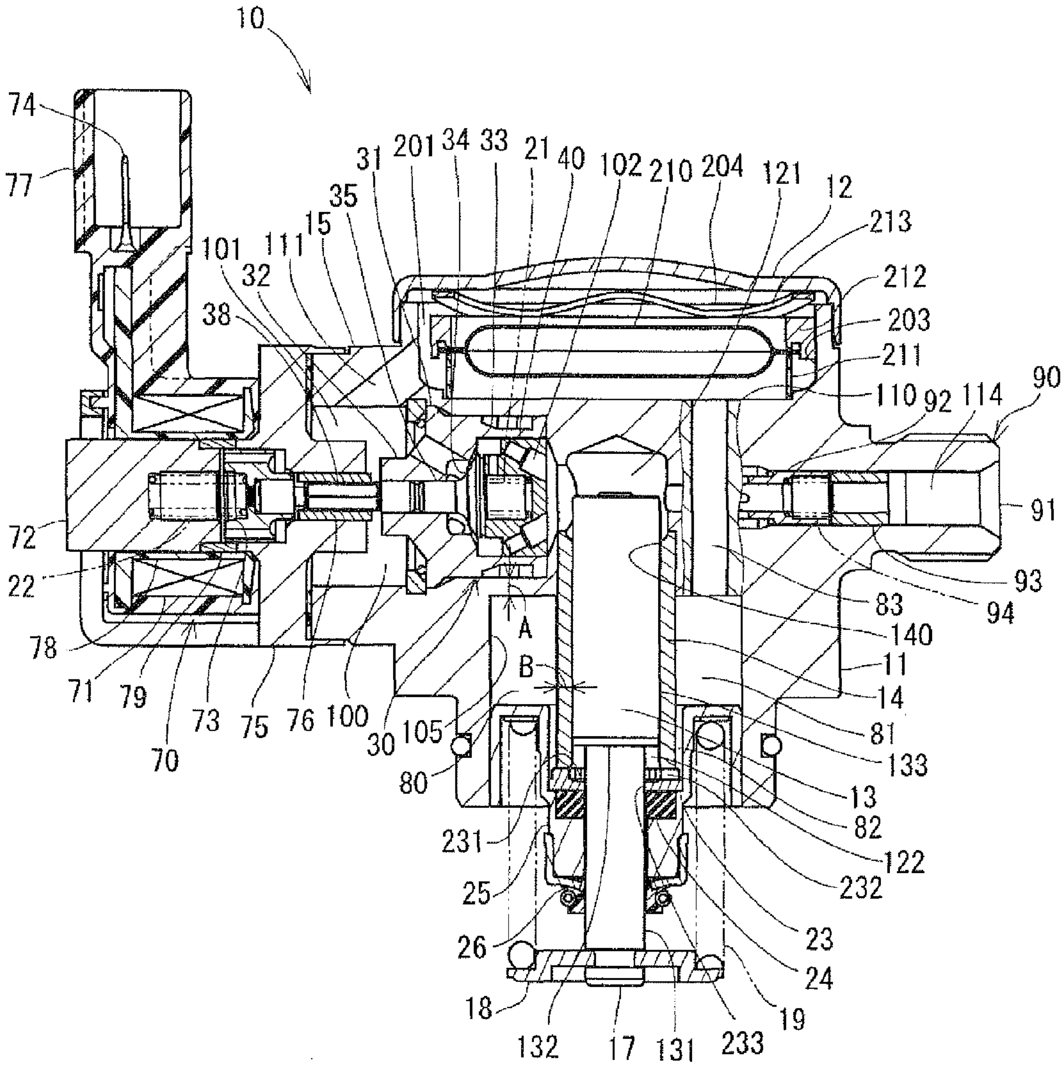
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FIG. 9

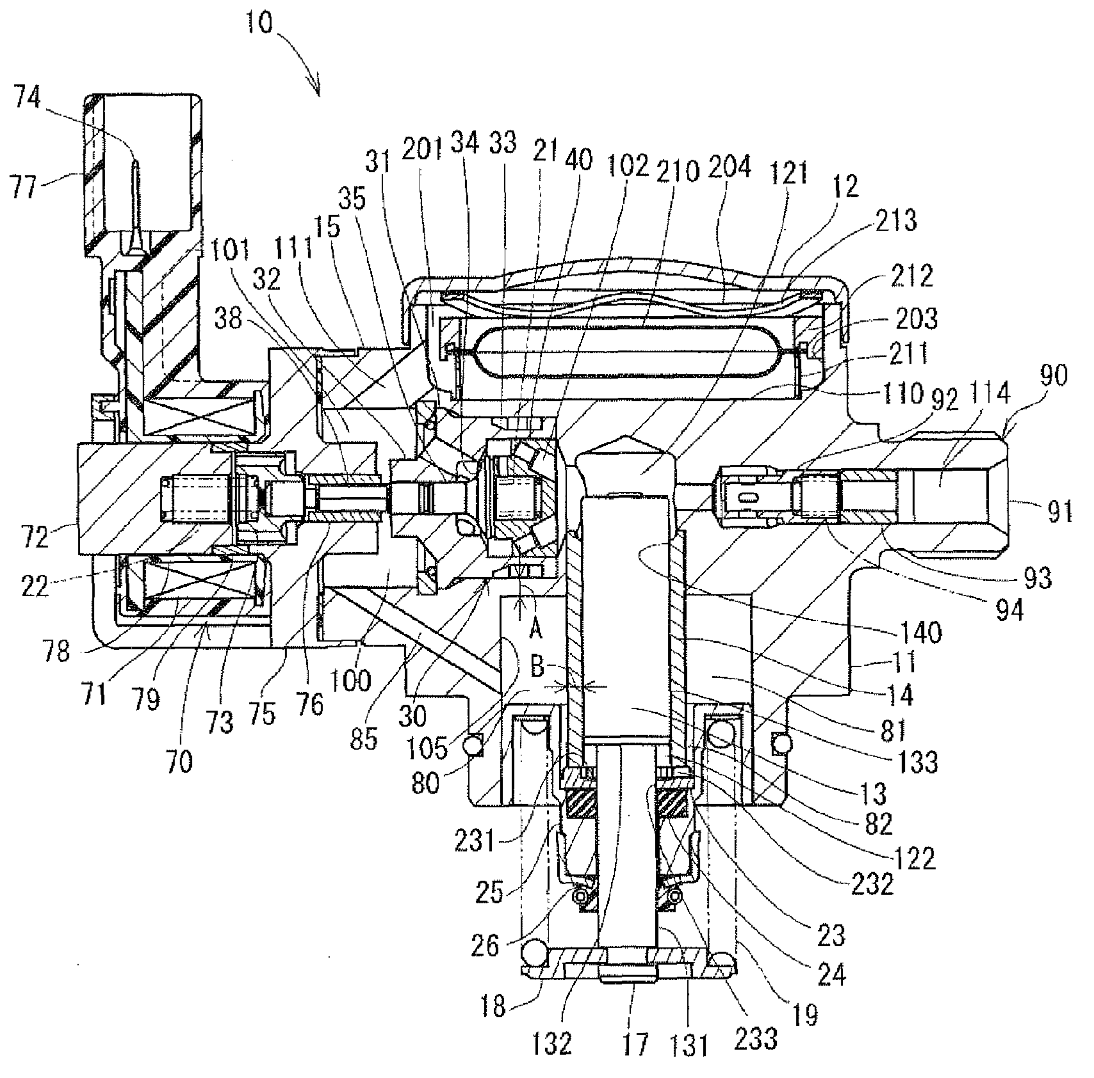
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FIG. 10

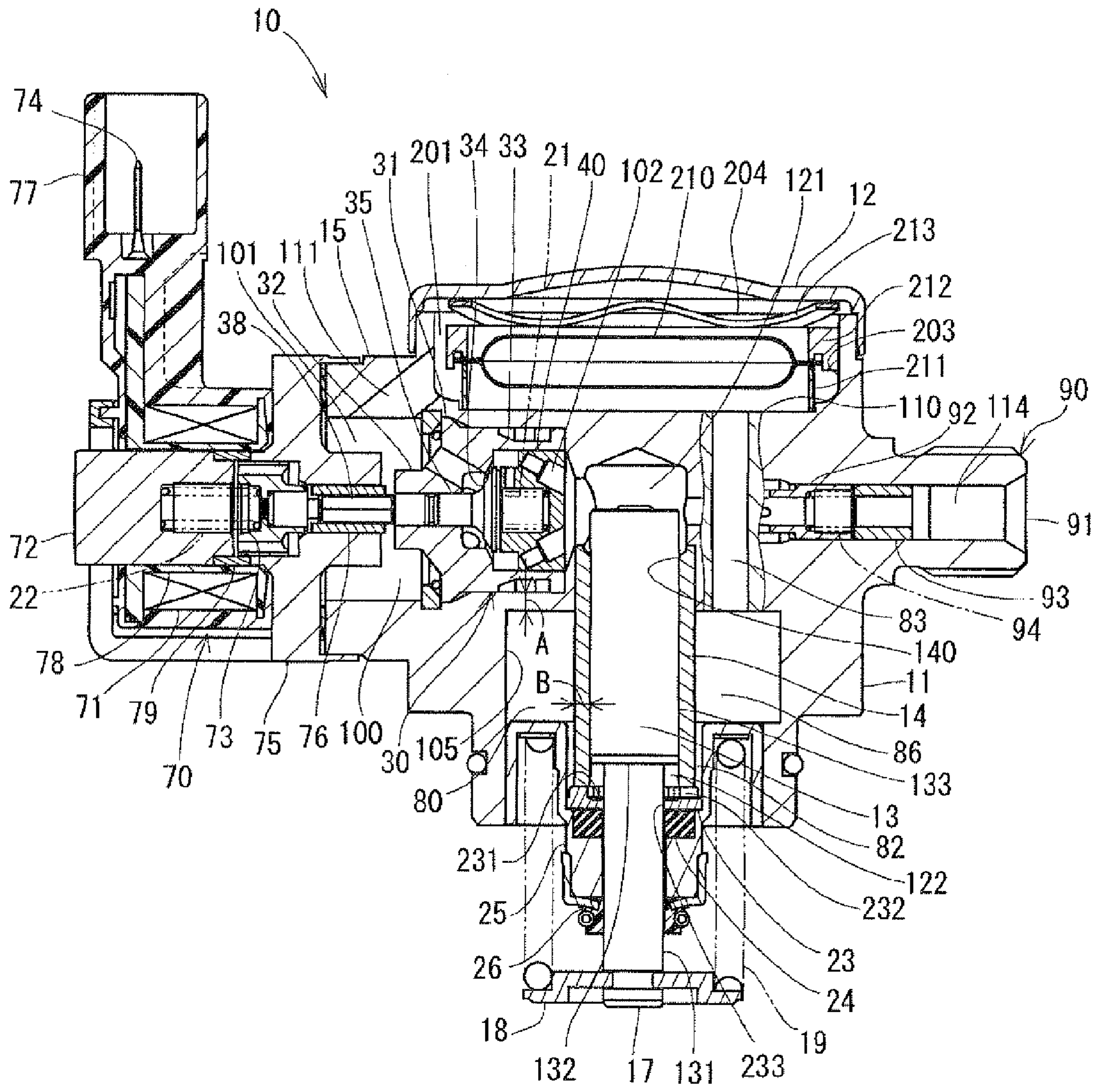

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FIG. 11

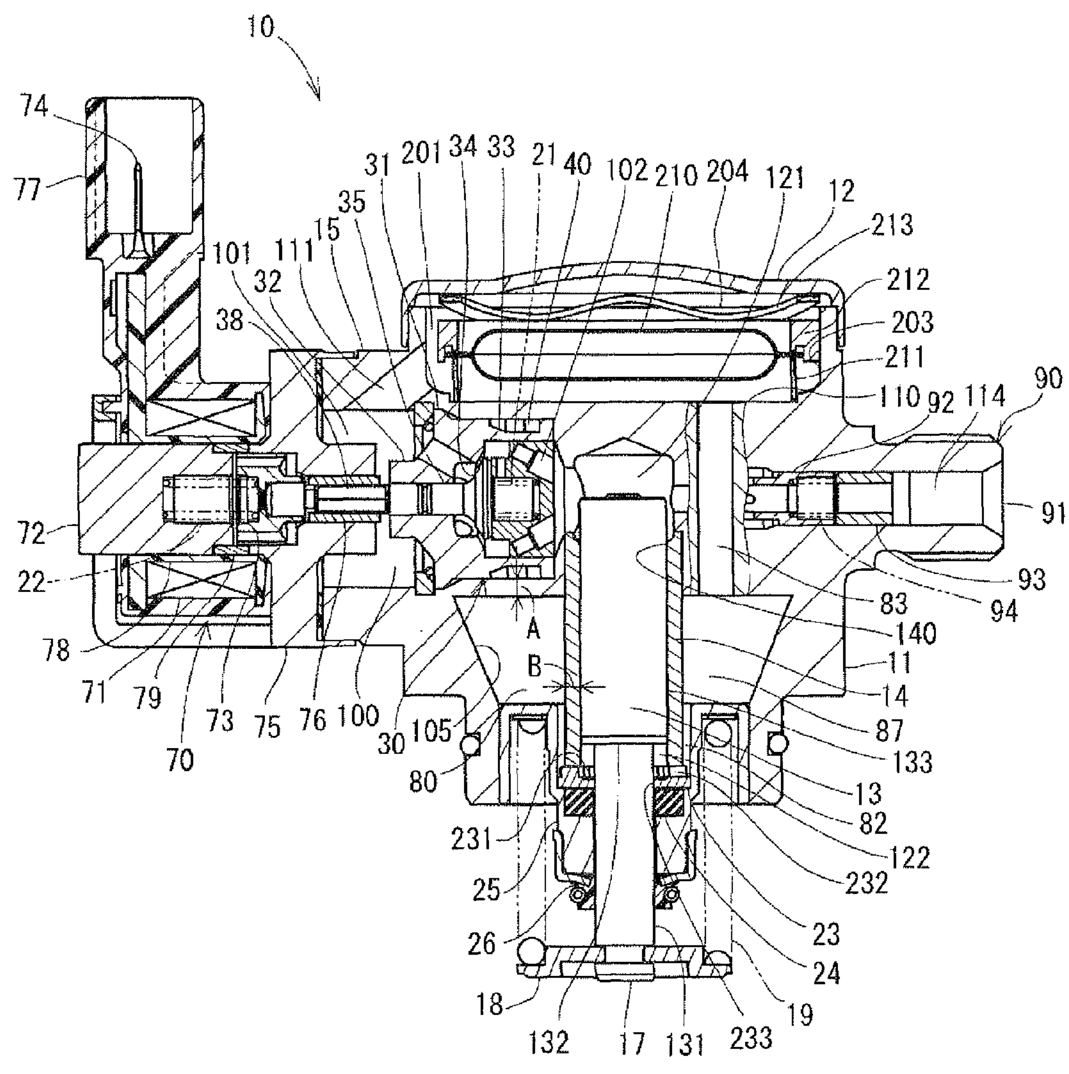
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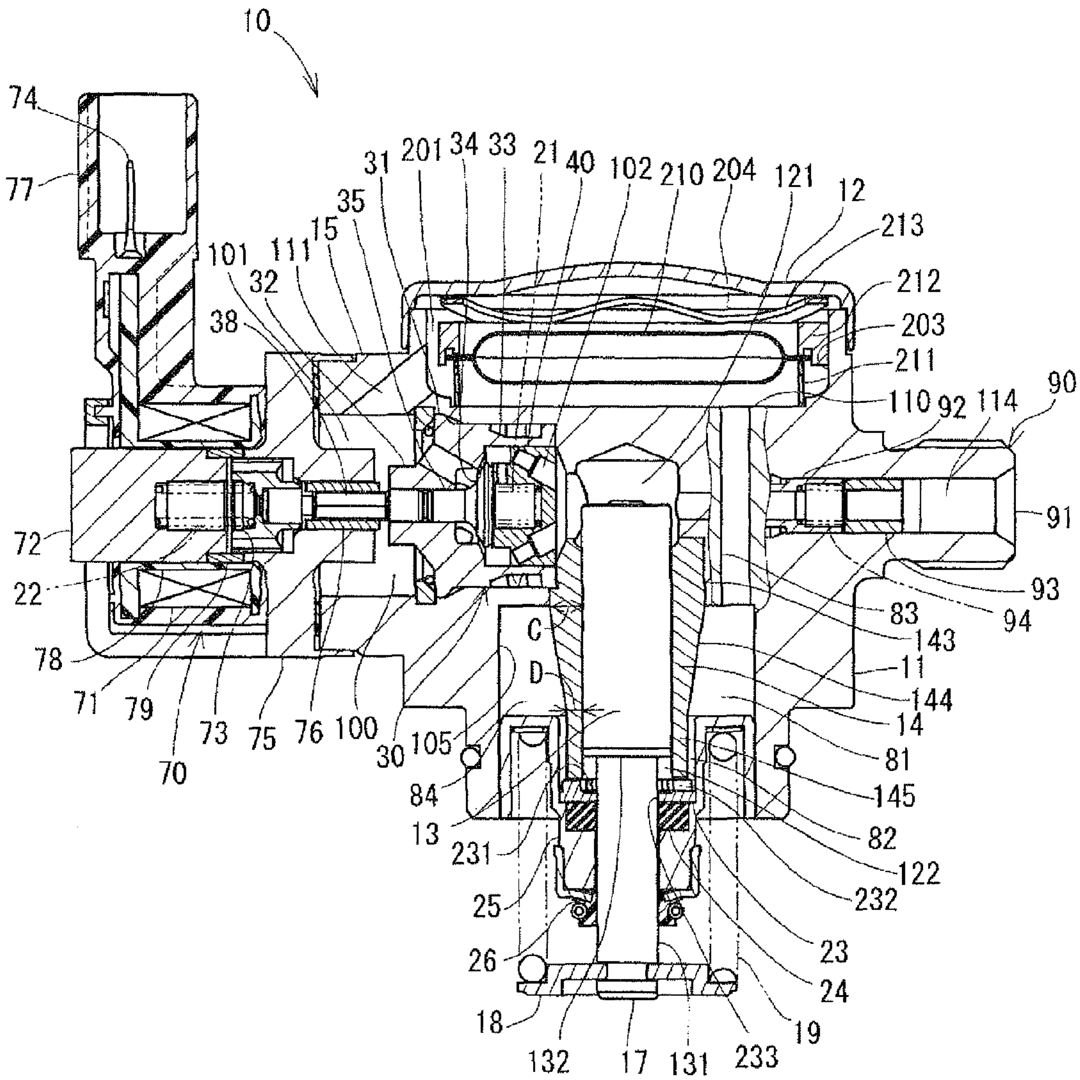
FIG. 12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HIGH-PRESSURE PUMP

CROSS-REFERENCE TO RELATED APPLICATION

This application is based on Japanese Patent Applications No. 2010-89360 filed on Apr. 8, 2010 and No. 2010-262312 filed on Nov. 25, 2010, the disclosures of which are incorporated herein by reference.

FIELD OF THE INVENTION

The present invention relates to a high-pressure pump used for an internal combustion engine.

BACKGROUND OF THE INVENTION

Conventionally, a fuel supply system which supplies fuel to an engine is equipped with a high-pressure pump which pressurizes the fuel suctioned from a fuel tank. The pressurized fuel discharged from the high-pressure pump is accumulated in a delivery pipe and is injected into a cylinder through an injector. Generally, a high-pressure pump is installed on an engine head. The high-pressure pump is comprised of a plunger and a cylinder. The plunger reciprocates in the cylinder to pressurize the fuel in a pressurization chamber.

Such a high-pressure pump receives heat from the engine, which may cause a deformation of the cylinder. The deformation of the cylinder gradually increases frictional heat between the cylinder and the plunger. It is likely that seizure may occur between the cylinder and the plunger. If the seizure occurs, a fuel pressure in a delivery pipe may be decreased and no fuel may be injected through a fuel injector. Finally, the engine may be stopped.

Patent Document 1 (JP-2008-2361A) shows that a high-pressure pump has a cylindrical bush made of heat-resistant material. This cylindrical bush is provided to a pump body through a cylinder holder and functions as cylinder, whereby a deformation of the cylinder is restricted.

Patent Document 2 (JP-2003-35239A) describes that a cylinder holder is made of material whose thermal conductivity is small and a thread portion of the cylinder holder is coated with resin, whereby heat transfer from a pump body to a cylinder is restricted.

Patent Document 3 (JP-2008-525713A) and Patent Document 4 (DE-10322599A) show that a cylinder is made of material which has high heat-resisting property, whereby it is restricted that the cylinder is deformed.

Patent Document 5 (JP-2010-106741A) shows a high-pressure pump which has a variable volume chamber on an opposite side of a pressurization chamber. A cylinder has a plurality of grooves on its outer surface. The fuel flows in and flows out from the variable volume chamber through these grooves, so that the cylinder is cooled by the fuel.

Patent Document 6 (US-77079966B2) shows a high-pressure pump which has a cylindrical clearance gap around a cylinder. This cylindrical clearance gap communicates with a pressurization chamber and a low-pressure fuel passage.

In the high-pressure pump shown in Patent Documents 1-4, a cylinder, a cylinder holder and a pump body are formed from separate pieces, which increases a number of parts. Further, the cylinder holder is made of low-heat-conductivity material and the thread portion of the cylinder holder is coated with resin material, which make the structure complicated and increases manufacturing steps.

Also, since the cylinder, the cylinder holder and the pump body are in contact with each other on their outer surfaces, it is likely that engine radiant heat may be transferred from the pump body to the cylinder.

In the high-pressure pump shown in Patent Document 5, since the grooves are formed around only one end portion of the cylinder, the entire cylinder is not always cooled.

The high-pressure pump shown in Patent Document 6 has no variable volume chamber. The cylindrical clearance gap communicates with only the low-pressure fuel passage. Thus, it is less likely that the fuel circulates to cool the cylinder.

SUMMARY OF THE INVENTION

The present invention is made in view of the above matters, and it is an object of the present invention to provide a high-pressure pump capable of enhancing a cooling efficiency of a cylinder.

According to a high-pressure pump of the present invention, a cylinder accommodates a plunger slidably. A pump body defines a pressurization chamber in which the fuel is pressurized by the plunger, a low-pressure fuel passage hydraulically connecting a fuel inlet and the pressurization chamber, and a discharge passage hydraulically connecting the pressurization chamber and a fuel outlet. A suction valve opens/closes a low-pressure fuel passage. A discharge valve opens/closes a discharge passage. The pump body further defines a cylindrical space around the cylinder, and the fuel flows into the cylindrical space from the low-pressure fuel passage. The cylindrical space is always filled with the fuel of low temperature.

Thus, the entire cylinder is cooled by the fuel flowing in the cylindrical space, which restricts a deformation of the cylinder. A fuel leakage and a seizure between the cylinder and the plunger can be restricted.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects, features and advantages of the present invention will become more apparent from the following description made with reference to the accompanying drawings, in which like parts are designated by like reference numbers and in which:

FIG. **1** is a schematic diagram showing a fuel supply system to which a high-pressure pump is applied, according to a first embodiment;

FIG. **2** is a cross-sectional view showing a high-pressure pump according to the first embodiment of the invention;

FIG. **3** is a partly sectional view in a direction of an arrow III in FIG. **2**;

FIG. **4** is a cross-sectional view taken along line IV-IV in FIG. **2**;

FIG. **5** is a chart showing an operation of the high-pressure pump according to the first embodiment;

FIG. **6** is a cross-sectional view showing a high-pressure pump according to a second embodiment of the invention;

FIG. **7** is a cross-sectional view showing a high-pressure pump according to a third embodiment of the invention;

FIG. **8** is a cross-sectional view showing a high-pressure pump according to a fourth embodiment of the invention;

FIG. **9** is a cross-sectional view showing a high-pressure pump according to a fifth embodiment of the invention;

FIG, **10** is a cross-sectional view showing a high-pressure pump according to a sixth embodiment of the invention;

FIG. **11** is a cross-sectional view showing a high-pressure pump according to a seventh embodiment of the invention; and

FIG. **12** is a cross-sectional view showing a high-pressure pump according to an eighth embodiment of the invention.

DETAILED DESCRIPTION OF EMBODIMENTS

Hereafter, embodiments of the present invention will be described hereinafter.

[First Embodiment]

FIG. **1** is a schematic view showing a fuel supply system including a high-pressure pump according to a first embodiment.

A portion encompassed by a dashed line represents a pump body **11** of a high-pressure pump **10**. Fuel in a fuel tank **1** is pumped up by a low-pressure pump **3** according to a command signal from an electronic control unit (ECU) **2**. The fuel is introduced to a fuel inlet **20** of a high-pressure pump **10** through a low-pressure fuel pipe **4**.

The fuel passed through the fuel inlet **20** flows into a supply passage **100** of a suction valve **30** through a filter **28**, a damper chamber **201** and an introduction passage **111**. The filter **28** removes foreign matters contained in the fuel. The damper chamber **201** attenuates pressure pulsation. In the present embodiment, a passage including a fuel passage between the fuel inlet **20** and the damper chamber **201**, the damper chamber **201**, the introduction passage **111**, and the supply passage **100** is referred to as a low-pressure fuel passage **101**.

The suction valve **30** opens/closes the supply passage **100** receiving hydraulic pressure in the supply passage **100** and magnetic force from a solenoid portion **70**. The fuel suctioned into a pressurization chamber **121** is pressurized by a plunger **13** which reciprocates along with a camshaft **5**. When a discharge valve **90** is opened, the pressurized fuel in the pressurization chamber **121** is discharged into a discharge passage **114** through a fuel outlet **91**. A configuration and an operation of the high-pressure pump **10** will be described later.

The fuel discharged from the high-pressure pump **10** is introduced into a common-rail **6**. Fuel injectors **7** and a fuel pressure sensor **8** are provided to the common-rail **6**.

A configuration and an operation of the high-pressure pump **10** will be described in detail. As shown in FIGS. **2** and **3**, the high-pressure pump **10** is provided with a pump body **11**, a plunger **13**, a damper chamber **201**, a suction valve **30**, a solenoid portion **70**, a discharge valve **90** and a pressure regulating portion **50**.

The pump body **11** forms a cylinder **14** therein. The cylinder **14** receives the plunger **13** reciprocatably. The plunger **13** has a head **17** with which a spring seat **18** is engaged. A spring **19** is provided between the spring seat **18** and an oil-seal holder **25**. One end of the spring **19** is engaged with the oil-seal holder **25** and the other end is engaged with the spring seat **18**. The spring **19** biases the spring seat **18** toward the camshaft **5**. The plunger **13** is in contacted with the camshaft **5** through a tappet **27**, so that the plunger **13** reciprocates to pressurize the fuel in the pressurization chamber **121**.

Next, the damper chamber **201** will be described in detail.

The pump body **11** has a concave portion **203**. A lid member **12** covers an opening **204** of the concave portion **203**. The lid member **12** and the concave portion **203** define the damper chamber **201** therebetween.

The damper chamber **201** accommodates a pulsation damper **210**, a first supporting member **211**, a second supporting member **212**, and a wavy spring **213**. The pulsation damper **210** is comprised of two metallic diaphragms in which air of specified pressure is sealed. The pulsation damper **210** reduces fuel pressure pulsation in the damper chamber **207**.

The first supporting member **211** is cylindrically shaped and has a plurality of apertures through which the fuel flows. The first supporting member **211** is engaged with a bottom concave **110** of the pump body **11**. The second supporting member **212** is also cylindrically shaped. The pulsation damper **210** is sandwiched between the first supporting member **211** and the second supporting member **212**.

The wavy spring **213** is arranged between the second supporting member **212** and the lid member **12** so that the second supporting member **212** is biased toward the pump body **11**. Thereby, the pulsation damper **210**, the first supporting member **211** and the second supporting member **212** are fixed in the damper chamber **201**.

The damper chamber **201** communicates with a fuel inlet (not shown) through a fuel passage (not shown). The fuel in the fuel tank **1** is supplied to the fuel inlet. The fuel in the fuel tank **1** is introduced into the damper chamber **201**.

Next, the suction valve **30** will be described in detail.

The pump body **11** has a cylindrical body portion **15** which extends perpendicularly relative to a center line of the cylinder **14**. The cylindrical body portion **15** defines the supply passage **100** therein. One end of the supply passage **100** is hydraulically connected to the pressurization chamber **121**. The damper chamber **201** and the supply passage **100** are connected with each other through the introduction passage **111**. The fuel is introduced into the pressurization chamber **121** through a passage between the fuel inlet and the damper chamber **201**, the damper chamber **201**, the introduction passage **111** and the supply passage **100**.

The valve body **31** is accommodated in the supply passage **100**. The valve body **31** has a small-diameter cylinder portion **32** and a large-diameter cylinder portion **33**. The large-diameter cylinder portion **33** has a valve seat **34**. The suction valve body **35** is arranged inside of the large-diameter cylinder portion **33**. The suction valve body **35** slides on an inner surface of the small-diameter cylinder portion **32**. The suction valve body **35** can sit on the valve seat **34**.

A stopper **40** is fixed on an inner surface of the large-diameter cylinder portion **33** to restrict a movement of the suction valve body **35** in its opening direction. A first spring **21** is provided between the stopper **40** and the suction valve body **35**. The first spring **21** biases the suction valve body **35** toward the valve seat **34**. The stopper **40** has a plurality of inclined passages **102**.

Next, the solenoid portion **70** will be described hereinafter.

The solenoid portion **70** is comprised of a coil **71**, a fixed core **72**, a movable core **73**, and a flange **75**. A coil **71** is wound around a spool **78** made of resign. The fixed core **72** is made from magnetic material and is accommodated inside of the coil **71**. The movable core **73** is made from magnetic material and confronts the fixed core **72**. The movable core **73** is slidably arranged in a flange **75**.

The flange **75** is made of magnetic material and is attached to the cylindrical body portion **15**. A cylindrical member **79** made of nonmagnetic material is disposed between the fixed core **72** and the flange **75** to prevent a magnetic short circuit therebetween. The flange **75** supports the fixed core **72** and the connector **77** on the pump body **11** and closes an opening end of the cylindrical body portion **15**. The flange **75** is provided with a guide cylinder **76**. A needle **38** is slidably arranged in the guide cylinder **76**. One end of the needle **38** is connected to the movable core **73** and the other end is engaged with the suction valve body **35**.

A second spring **22** is provided between the fixed core **72** and the movable core **73**. The second spring **22** biases the movable core **73** toward the suction valve body **35** with a biasing force which is grater than a biasing force of the first spring **21**. When the coil **71** is not energized, the movable core **73** and the fixed core **72** are apart from each other by the biasing force of the second spring **22**. Thereby, the movable core **73** and the needle **38** are moved toward the suction valve body **35**, so that the needle **38** pushes the suction valve body **35** to be opened.

A variable volume chamber **122** will be described hereinafter.

The plunger **13** has a small-diameter portion **131** and a large-diameter portion **133**. A stepped surface **132** is formed between the small-diameter portion **131** and the large-diameter portion **133**. An annular plunger stopper **23** is provided to the stepped surface **132**. The plunger stopper **23** has a concave portion **231** and grooves **232** which radially extend from the concave portion **231**. The plunger stopper **23** has a through hole **233** at its center. The small-diameter portion **131** is inserted into the through hole **233**.

The pump body **11** has an annular concave portion **105**. An oil-seal holder **25** is inserted into the annular concave portion **105**. The small-diameter portion **131** is surrounded by the oil-seal holder **25**. The oil-seal holder **25** is fixed on an inner surface of the annular concave portion **105** through the seal member **24**. The seal member **24** regulates the thickness of the fuel around the small-diameter portion **131** to avoid a fuel leakage. An oil seal **26** is provided to the oil-seal holder **25**. The oil seal **26** regulates the thickness of the oil around the small-diameter portion **131** to avoid an oil leakage.

A variable volume chamber **122** is defined by the stepped surface **132**, the outer wall surface of the small-diameter portion **131**, an inner wall surface of the cylinder **14**, the concave portion **231**, the grooves **232** and an annular space surrounded by the seal member **24**.

A cylindrical space **80** is defined between the inner wall of the oil-seal holder **25** and the inner wall of the annular concave portion **105**. The cylindrical space **80** is coaxially formed around the cylinder **14**. The cylindrical space **80** is comprised of a first cylindrical space **81** and a second cylindrical space **82**. The first cylindrical space **81** is formed around the cylinder **14** and the second cylindrical space **82** is formed between an inner wall surface of the oil-seal holder **25** and the outer wall surface of the cylinder **14**. The first cylindrical space **81** communicates with the damper chamber **201** through a communication passage **83** which is defined in the pump body **11**. The second cylindrical space **82** communicates with the variable volume chamber **122** through the grooves **232**. Thereby, the cylindrical space **80** communicates with both the damper chamber **201** and the variable volume chamber **122**.

The cylindrical space **80** axially extends from the variable volume chamber **122** toward the pressurization chamber **121** around the cylinder **14**. If a wall thickness "A" between the supply passage **100** and the cylindrical space **80** is made thin, it is likely that the inner wall of the pump body **11** defining the supply passage **100** may be deformed due to the fuel pressure in the supply passage **100**. If the supply passage **100** is deformed, clearance gaps are generated in the suction valve **30**, which causes fuel leakage. Therefore, according to the present embodiment, the wall thickness "A" is defined in such a manner that the supply passage **100** is hardly deformed due to the fuel pressure in the supply passage **100**.

Also, if a wall thickness "B" of the cylinder **14** is made small, it is likely that the cylinder **14** may be deformed due to a fuel pressure between the cylinder **14** and the plunger **13**. According to the present embodiment, the wall thickness "B" is defined in such a manner that the cylinder **14** is hardly deformed due to the fuel pressure between the cylinder **14** and the plunger **13**.

Then, the discharge valve **90** will be described hereinafter.

The discharge valve **90** controls a discharge of fuel pressurized in the pressurization chamber **121**. The discharge valve **90** is comprised of a discharge valve body **92**, a regulation member **93**, a spring **94** and like. The pump body **11** defines a discharge passage **114** which extends perpendicularly relative to the center axis of the cylinder **14**. The discharge passage **114** hydraulically connects the pressurization chamber **121** and the fuel outlet **91**. The discharge valve body **92** is cup-shaped and is slidably accommodated in the discharge passage **114**. As shown in FIG. **3**, when the discharge valve body **92** sits on the valve seat **95**, the discharge passage **114** is closed. The regulation member **93** is fixed on an inner wall surface of the discharge passage **114**. One end of the spring **94** is engaged with the regulation member **93** and the other end is engaged with the discharge valve body **92**. The spring **94** biases the discharge valve body **92** toward the pressurization chamber **121**.

When the fuel pressure in the pressurization chamber **121** exceeds a specified value, the discharge valve body **92** moves away from the valve seat **95**, whereby the fuel in the pressurization chamber **121** is discharged through the fuel outlet **91**.

When the fuel pressure in the pressurization chamber **121** is decreased, the discharge valve body **92** seats on the valve seat **95**. Thereby, a reverse flow of the fuel from the fuel outlet **91** toward the pressurization chamber **121** is avoided.

Referring to FIG. **3**, the pressure regulating portion **50** will be described hereinafter.

The pump body **11** has a relief passage **51** which extends perpendicularly relative to the center axis of the cylinder **14**. One end of the relief passage **51** is hydraulically connected to both the discharge passage **114** and the pressurization chamber **121**. A plug **55** closes an opening of the relief passage **51** at an outside wall of the pump body **11**. The pressure regulating portion **50** is comprised of a relief valve **52**, an adjustment pipe **53**, a spring **54**, and a constant residual pressure valve **60**.

The relief valve **52** is formed cylindrical and is slidably arranged in the relief passage **51**. The relief valve **52** has an inner passage in which the constant residual pressure valve **60** is accommodated. One end of the spring **54** is engaged with the relief valve **52**, and the other end is engaged with the adjustment pipe **53**. The relief valve **52** is biased toward a valve seat **56** by the spring **54**. When the relief valve **52** sits on the valve seat **56**, the relief passage **51** is closed. When the relief valve **52** moves apart from the valve seat **56**, the relief passage **51** is opened.

The adjustment pipe **53** adjusts a load of the spring **54**.

The constant residual pressure valve **60** is a check valve which opens when the fuel pressure in the delivery pipe is greater than a specified value.

Referring to FIGS. **2** and **5**, an operation of the high-pressure pump **10** will be described hereinafter.

(1) Suction Stroke

When the plunger **13** slides down from the top dead center toward the bottom dead center, the volume of the pressurization chamber **121** is increased. The discharge valve body **92** sits on the valve seat **95** to close the discharge passage **114**. The suction valve body **35** receives a differential pressure between the pressurization chamber **121** and the supply passage **100** to be opened against the biasing force of the first spring **21**. Since the coil **71** is not energized at this moment, the movable core **73** and the needle **38** moves rightward against the biasing force of the second spring **22**. The needle **38** is brought into contact with the suction valve body **35** so that the suction valve body **35** is maintained to be opened. The fuel is suctioned from the low-pressure fuel passage **101** to the pressurization chamber **121**.

It should be noted that a control signal transmitted from the ECU **2** to the coil **71** is referred to as a solenoid control signal and a position of the needle **38** is referred to as a needle position in FIG. **5**.

In the suction stroke, the plunger **13** slides down and the volume of the variable volume chamber **122** is decreased. The fuel in the variable volume chamber **122** is discharged into the damper chamber **201** through the cylindrical space **80** and the communication passage **83**. At this moment, the fuel flows along an outer surface of the cylinder **14** from the second cylindrical space **82** to the first cylindrical space **81**, so that the cylinder **14** is cooled by the fuel.

A ratio of cross sectional area between the large-diameter portion **133** and the variable volume chamber **122** is about "1:0.6". Thus, a ratio between an increased volume of the pressurization chamber **121** and a decreased volume of the variable volume chamber **122** is "1:0.6". About 60% of the fuel suctioned into the pressurization chamber **121** is supplied from the variable volume chamber **122** through the cylindrical space **80** and the low-pressure fuel passage **101**, and about 40% of the fuel is suctioned from the fuel inlet. Thus, a suction efficiency of the fuel to the pressurization chamber **121** is improved.

(2) Metering Stroke

When the plunger **13** slides up from the bottom dead center toward the top dead center, the volume of the pressurization chamber **121** is decreased. At this moment, since the coil **71** is not energized, the needle **38** and the suction valve body **35** are biased rightward in FIG. **2**. The supply passage **100** is maintained to be opened. Thus, the fuel in the pressurization chamber **121** is returned to the low-pressure fuel passage **101** through the suction valve **30**. The pressure in the pressurization chamber **121** does not increase.

While the plunger **13** slides up from the bottom dead center to the top dead center, the coil **71** is energized according to a control signal from the ECU **2**. The coil **71** generates magnetic field and magnetic attraction force is generated between the fixed core **72** and the movable core **73**. When this magnetic attraction force becomes greater than the biasing force of the first and second springs **21**, **22**, the movable core **73** and the needle **38** move toward the fixed core **72**. The suction valve body **35** sits on the valve seat **34** to close the supply passage **100**.

(3) Pressurization Stroke

From the time the suction valve body **35** sits on the valve seat **34**, the fuel pressure in the pressurization chamber **121** increases while the plunger **13** slides up. When the fuel pressure in the pressurization chamber **121** exceeds a specified value, the discharge valve body **92** moves away from the valve seat **95**. Thereby, high-pressure fuel pressurized in the pressurization chamber **121** is discharged from the fuel outlet **91** through the discharge passage **114**.

It should be noted that the coil **71** is deenergized in the pressurization stroke. The suction valve body **35** is maintained to be closed.

In the metering stroke and the pressurization stroke, the plunger **13** slides up and the volume of the variable volume chamber **122** increases. Therefore, the fuel in the damper chamber **201** flows into the variable volume chamber **122** through the communication passage **83** and the cylindrical space **80**. Since the fuel in the damper chamber **201** has low temperature, the space around the cylinder **14** is filled with low-temperature fuel, whereby the cylinder **14** is cooled.

At this time, about 60% of the fuel discharged into the damper chamber **201** from the pressurization chamber **121** is suctioned into the variable volume chamber **122** from the damper chamber **201** through the communication passage **83** and the cylindrical space **80**. Thereby, fuel pressure pulsation is reduced about 60%.

The ECU **2** controls a timing at which the coil **71** is energized, whereby the discharge quantity of the high-pressure pump **10** is adjusted.

According to the above embodiment, following functional advantages can be achieved.

The cylindrical space **80** is coaxially formed around the cylinder **14**. This cylindrical space **80** communicates with both the variable volume chamber **122** and the low-pressure fuel passage **101**. Thus, while the plunger **13** reciprocates, the fuel is introduced into the cylindrical space **80** alternately from the low-pressure fuel passage **101** and the variable volume chamber **122**. The cylindrical space **80** is always filled with the fuel of low temperature. The entire outer surface of the cylinder **14** can be surely cooled.

Further, the volume of the first cylindrical space **81** is greater than that of the second cylindrical space **82**. The first cylindrical space **81** has high cooling capacity. The fuel flows fast in the second cylindrical space **82**. In a case heat is generated around the variable volume chamber **122**, the cylinder **14** is cooled by the fuel in the second cylindrical space **82**. This generated heat is axially transferred along the cylinder **14** so as to be cooled by the fuel in the first cylindrical space **81**. Thus, the cylinder **14** is effectively cooled.

Thermal conductivity of gasoline is 0.01-0.07 kcal/m·h·□, which is rather smaller than that of metallic material. Thus, the heat transferred form the engine head to the pump body **11** and the heat which the pump body **11** receives from an engine room are hardly transferred to the cylinder **14** from the pump body **11** due to the fuel flowing in the cylindrical space **80**.

[Second Embodiment]

Referring to FIG. **6**, a second embodiment of the invention will be described. In each of following embodiments, the substantially same parts and the components as those in the first embodiment are indicated with the same reference numeral and the same description will not be reiterated.

In the second embodiment, the cylindrical space **84** is shaped tapered. The cylinder **14** has a tapered portion **141** and a cylindrical portion **142**. A wall thickness "C" of the cylinder **14** is thicker than a wall thickness "D" of the cylinder **14**.

A fuel film is formed in a clearance between the cylinder **14** and the plunger **13**. In this clearance, the fuel pressure decreases along a direction from the pressurization chamber **121** to the variable volume chamber **122** according to Hagen-Poiseuille equation. Corresponding to the variation in fuel pressure, the cylinder **14** has a tapered portion **141** so that a deformation of the cylinder **14** is restricted. Thereby, frictional heat is restricted between the cylinder **14** and the plunger **13**.

[Third Embodiment]

Referring to FIG. **7**, a third embodiment of the invention will be described. A plurality of communication passages **83** hydraulically connecting the cylindrical space **80** and the damper chamber **201** are formed. These communication passages **83** extend axially in parallel with the cylinder **14**. Each of communication passages **83** has an opening **831** which opens to the cylindrical space **80**.

While the plunger **13** reciprocates and the volume of the variable volume chamber **122** is varied, the fuel circulates between the variable volume chamber **122** and the cylindrical space **80**. The fuel circulates between the cylindrical space **80** and the damper chamber **201** through the openings **831** and communication passages **83**. The fuel of low temperature is supplied from the fuel tank **1** to the damper chamber **201**.

Thus, the variable volume chamber **122** and the cylindrical space **80** are filled with the fuel of low temperature.

The communication passages **83** improve the circulation of the fuel between the cylindrical space **80** and the damper chamber **201**. Thus, since the fuel in the cylindrical space **80** becomes low temperature, it is restricted that heat is transferred from the pump body **11** to the cylinder **14**. The cylinder **14** is effectively cooled.

[Fourth Embodiment]

Referring to FIG. **8**, a fourth embodiment of the invention will be described. In the present embodiment, the pump body **11** and the cylinder **14** are separately made. The cylinder **14** is press-fitted into the pump body **11**. In the present embodiment, the cylinder **14** is made of martensite stainless steel which has relatively high hardness, and the pump body **11** is made of ferrite stainless of which hardness is lower than that of the cylinder **14**. Thus, deformation of the cylinder **14** can be restricted. Also, a fuel leakage and a seizure between the cylinder **14** and the plunger **13** can be restricted. Further, the fuel passage can be easily formed in the pump body **11**, which reduces manufacturing cost.

[Fifth Embodiment]

Referring to FIG. **9**, a fifth embodiment of the invention will be described. A communication passage **85** hydraulically connects the cylindrical space **80** and the supply passage **100**. In the metering stroke, the fuel discharged from the pressurization chamber **121** to the supply passage **100** is introduced into the variable volume chamber **122** through the supply passage **100**, the communication passage **85** and the cylindrical space **80** without flowing into the damper chamber **201**. Therefore, since the flow resistance between the pressurization chamber **121** and the variable volume chamber **122** becomes smaller, a suction efficiency from the pressurization chamber **121** to the variable volume chamber **122** can be enhanced.

A differential quantity of fuel between the fuel discharge from the pressurization chamber **121** and the fuel suctioned into the variable volume chamber **122** flows into the damper chamber **201**. Thereby, the fuel pressure pulsation transmitted to the damper chamber **201** can be decreased.

In the suction stroke, the volume of the variable volume chamber decreases. The fuel discharged from the variable volume chamber **122** into the supply passage **100** through the cylindrical space **80** and the communication passage **85** can flow into the pressurization chamber **121** along a shortest pass. Thus, a suction efficiency of the fuel from the variable volume chamber **122** to the pressurization chamber **121** is improved. The fuel flows in the cylindrical space **80** efficiently and the cylinder **14** is effectively cooled.

[Sixth Embodiment]

Referring to FIG. **10**, a tenth embodiment of the invention will be described. A center line of the first cylindrical space **86** is made eccentric relative to a center line of the cylinder **14**. Thus, the volume of the first cylindrical space **86** can be made larger, whereby the cylinder **14** is cooled more effectively.

[Seventh Embodiment]

FIG. **11** shows a seventh embodiment of the invention. In the seventh embodiment, the first cylindrical space **87** is shaped tapered.

Also in the seventh embodiment, the same advantages as those in the sixth embodiment can be obtained.

[Eighth Embodiment]

Referring to FIG. **12**, an eighth embodiment of the invention will be described. The cylinder **14** is formed separately from the pump body **11** and is shaped tapered. The cylinder **14** is comprised of a large-diameter portion **143**, a taper portion **144** and a small-diameter portion **145**. A wall thickness "C" of the taper portion **144** is greater than a wall thickness "D" of the taper portion **144**.

In the clearance between the cylinder **14** and the plunger **13**, the fuel pressure decreases along a direction from the pressurization chamber **121** to the variable volume chamber **122**. Corresponding to this variation in fuel pressure, the cylinder **14** has a tapered portion **144** so that a deformation of the cylinder **14** is restricted. Thereby, frictional heat is restricted between the cylinder **14** and the plunger **13**.

Further, when the large-diameter portion **143** is press-inserted into the pump body **11**, it is restricted that the large-diameter portion **143** is deformed in a radial direction.

[Other Embodiment]

The shape of cross section of the cylindrical space is not limited to the above embodiments. Any shape of cross section of the cylindrical space can be applied.

The present invention is not limited to the embodiment mentioned above, and can be applied to various embodiments.

What is claimed is:

1. A high-pressure pump comprising:

a plunger for pressurizing a fuel;

a cylinder accommodating the plunger reciprocatably in its axial direction, the cylinder having a large-diameter cylindrical portion, a tapered portion and a small-diameter cylindrical portion arranged sequentially in an axial direction of the cylinder, wherein the tapered portion has an increasing wall thickness that gradually increases in the axial direction of the cylinder toward a pressurization chamber, wherein each of the large-diameter cylindrical portion and the small-diameter cylindrical portion has a constant wall thickness, and wherein the small-diameter cylindrical portion is seamlessly and integrally connected to the tapered portion;

a pump body defining the pressurization chamber in which the fuel is pressurized by the plunger, a low-pressure fuel passage hydraulically connecting a fuel inlet and the pressurization chamber, and a discharge passage hydraulically connecting the pressurization chamber and a fuel outlet;

a suction valve opening/closing the low-pressure fuel passage;

a discharge valve opening/closing the discharge passage; and

a variable volume chamber defined in the cylinder opposite to the pressurization chamber relative to the plunger, wherein a volume of the variable volume chamber is varied according to a reciprocation of the plunger; wherein

the pump body further defines a cylindrical space around at least the small-diameter cylindrical portion of the cylinder,

the cylindrical space communicates with the variable volume chamber and a communication passage extending from the low-pressure fuel passage,

and the fuel flows into the cylindrical space from the low-pressure fuel passage so as to cool the cylinder.

2. A high-pressure pump according to claim **1**, wherein

the cylindrical space is comprised of a first cylindrical space with which the low-pressure fuel passage communicates and a second cylindrical space,

the first cylindrical space and the second cylindrical space are aligned in an axial direction of the cylinder in such a manner that the first cylindrical space is close to the pressurization chamber more than the second cylindrical space,

a volume of the first cylindrical space is greater than that of the second cylindrical space, and

the fuel flows on outer surfaces of the tapered portion and the small-diameter cylindrical portion.

3. A high-pressure pump according to claim **2**, wherein

an inner diameter of the first cylindrical space is greater than that of the second cylindrical space, and

the fuel flows into the variable volume chamber.

4. A high-pressure pump according to claim **1**, wherein

the cylinder has a wall thickness which is thick enough to endure a fuel pressure between the cylinder and the plunger.

5. A high-pressure pump according to claim **1**, wherein

the pump body defines a fuel passage hydraulically connecting the fuel inlet and the fuel outlet, and this fuel passage is arranged radially outside of the pressurization chamber.

6. A high-pressure pump according to claim **5**, wherein

the fuel passage is opened/closed by a suction valve or a discharge valve.

7. A high-pressure pump according to claim **1**, further comprising a plurality of communication passages which hydraulically connect the cylindrical space and the low-pressure fuel passage.

8. A high-pressure pump according to claim **7**, wherein

the low-pressure fuel passage includes a damper chamber into which the fuel flows from the fuel inlet and a supply passage which hydraulically connects the damper chamber and the pressurization chamber, and

the communication passages hydraulically connect the cylindrical space and the damper chamber.

9. A high-pressure pump according to claim **1**, wherein

a center axis of the cylindrical space is eccentric relative to a center axis of the cylinder.

10. A high-pressure pump according to claim **1**, wherein the cylindrical space is tapered.

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